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Scientific Computing In The Soviet Union

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Encouraged by *perestroika*, high-speed and parallel computing as well as major network projects are underway for Soviet scientists

In the last decade, the Soviet Union has placed increased emphasis on the development of high-speed computers and networks for use in scientific, economic, and military applications. When Communist Party General Secretary Mikhail Gorbachev labeled supercomputer development a "top priority task for our science and economy" in April, 1987, he added new urgency to the production of machines that would both support activities in these applications and also serve as high-profile standard-bearers for *perestroika*, his program of restructuring and modernization for the nation. The Soviets have also undertaken some major projects in networking, including the creation of a nationwide packet-switched network for the Academy of Sciences, work on network access to databases on scientific literature, and local area networks at a number of institutes.

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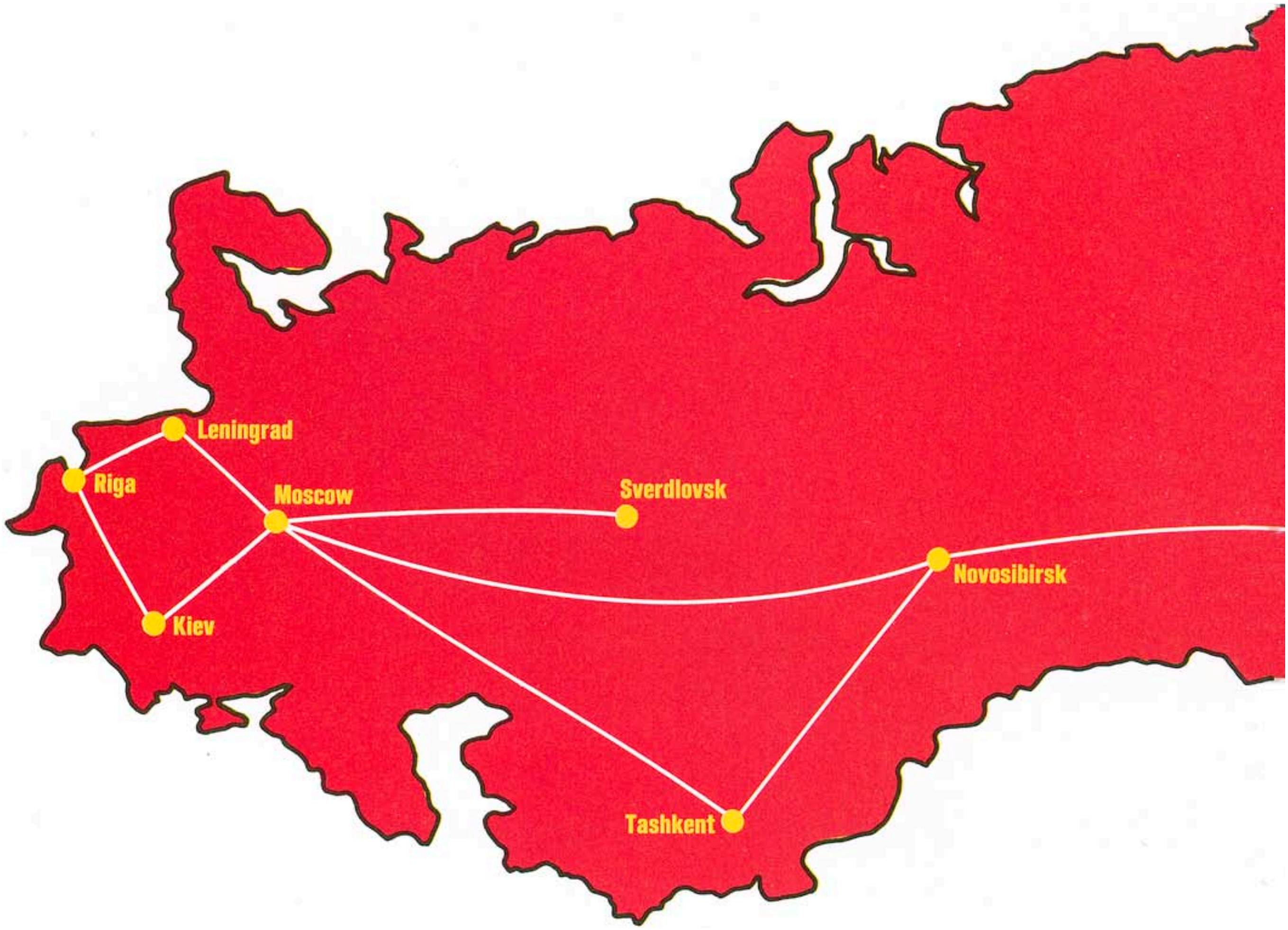
About a dozen high-speed and parallel architecture projects are in progress, and leaders in the field are projecting a prototype 1 giga instructions per second (GIPS) machine by 1990, and a prototype 10 GIPS machine by around 1995. Several of these machines are described briefly in Tables 1 and 2. However, in spite of the increased priority and profile, Soviet scientific researchers remain severely handicapped by a lack of widely available and reliable high-speed systems.

Since the mid-1960s, the backbone of Soviet scientific computing has been the BESM-6 uniprocessor. This 1 million instructions per second (MIPS) machine was first developed in 1964 and remained in production until around 1977. It is still widely used, and as recently as 1986 a section of a major conference was devoted to interfacing various peripherals with BESM-6s. Although its main and peripheral storage are extremely constraining by current standards, it remains in use, thanks to a considerable amount of applications and systems software, the availability of qualified BESM-6 maintenance personnel in a general computing environment that is notorious for service and maintenance problems, and a shortage of more powerful and more modern machines to replace it.

The BESM-6's developer, the Institute of Precision Mechanics and Computer Technology in Moscow (ITMVT), did not begin extended production of another openly announced large scientific computer until the El'brus-1 in 1979. This gap was most likely due to a combination of over-ambitious designs, designs which could not easily be mass produced, and leadership changes in 1973-1974. Both the El'brus-1 and El'brus-2 apparently suffer from problems that seriously undermine user confidence, and neither has been produced in the quantities



needed to replace a sizeable fraction of BESM-6s.

To ease the transition to the El'brus, a special El'brus processor which is software compatible with the BESM-6 was developed, giving BESM-6 software access to a faster processor and greater amounts of peripheral storage. Apparently, this processor was such that some BESM-6 maintenance experience could be transferred as well. It would not be surprising if this was the only, or at least the most extensively used, central processing unit (CPU) at many current El'brus installations. In spite of a tarnished reputation among users, the ITMVT is proceeding with work on a 16-processor, 1 GIPS El'brus-3 which, according to its director, G. G. Ryabov, will be in serial production by 1995.

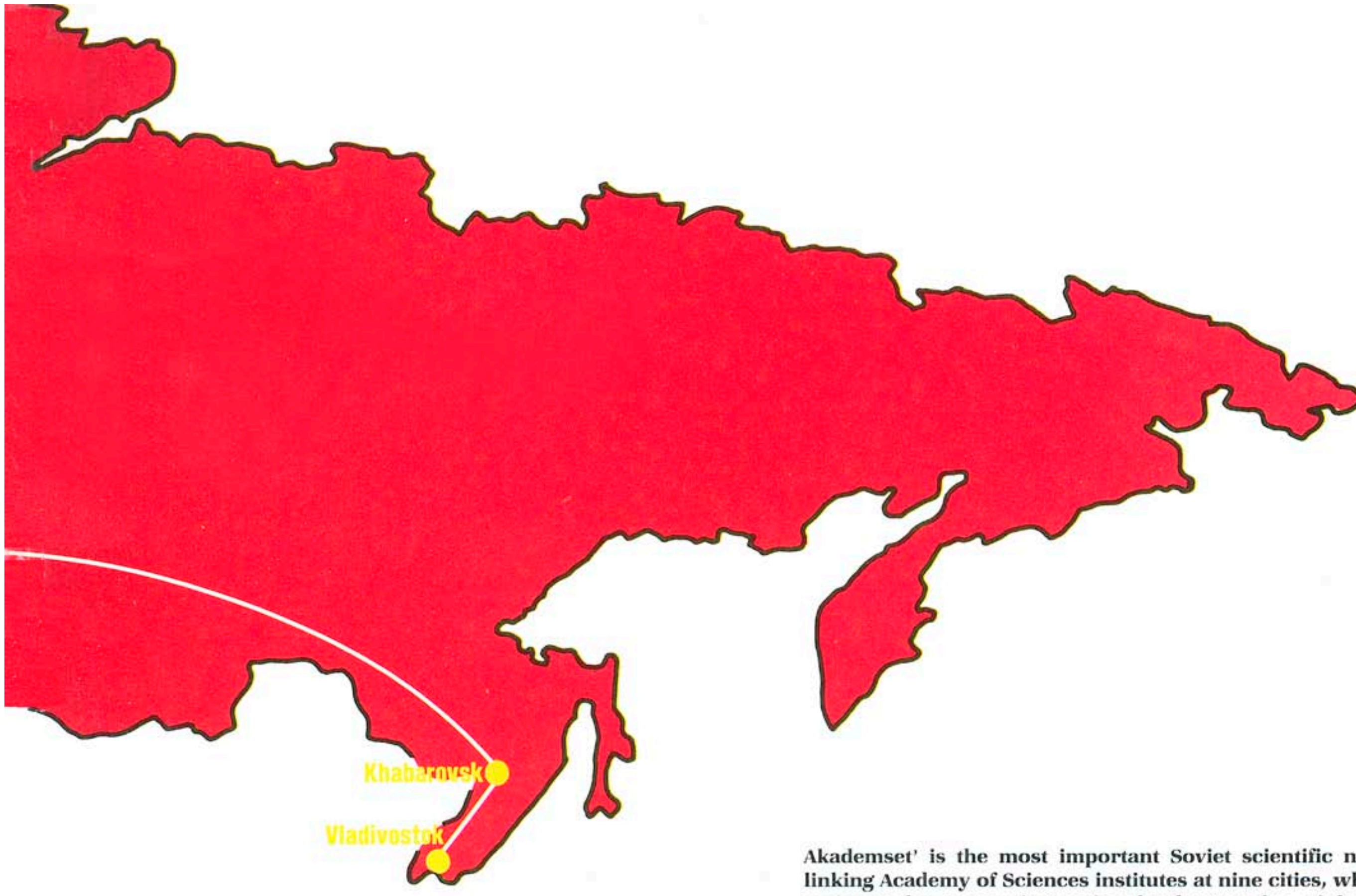
Most high-speed computer research is being done in Academy of Sciences institutes. The Academy has strongly endorsed such projects, seeing an opportunity to regain the prominence in computer development which it had in the 1960s before the start of the ES program–the effort to mass produce functional duplicates of IBM mainframes for the general economy. One high-profile project called Start, centered in Novosibirsk, has developed the MARS-M multiprocessor for numerical computation and 32-bit workstations. Start represents the first Soviet experiment with "temporary scientific technical complexes" (VNTK) in which specific projects, rather than institutes, are funded, in an effort to make it easier for specialists from a variety of institutes to consolidate their efforts toward a specific goal.

Low Production

The Academy lacks production facilities, and must rely on the industrial ministries to manufacture the machines it designs. This division of labor has often resulted in a mismatch between design specifications and the components available to support them. The Academy has a history of designing systems which are not easily manufactured in quantity; often the ministries must rework large portions of a design before they can produce the machine. The computer manufacturing ministries are also dependent on the chemical and electronics ministries for many crucial base materials and components. Continuing problems with mass production of items and poor interministry interfaces frequently results in quantitative and qualitative problems with components. Furthermore, the Academy does not have the authority to dictate production requirements to industry. To reduce some of these problems, the Academy has established a number of support industries of its own for the development of VLSI design tools, super-pure materials, and so on.

While these efforts may facilitate high-speed computer development, in the near future the bulk of scientific computing will still be borne by a combination of BESM-6s and ES mainframes and some attached array processors. An example of the latter, the Bulgarian IZOT 1703 has recently entered series production in reported quantities of some tens of units per year.

In addition to insufficient computing power, Soviet scientists must



Akademset' is the most important Soviet scientific network, linking Academy of Sciences institutes at nine cities, which are major nodes supporting regional subnetworks. Links on the map represent the network topology and not the physical location of the links.

also contend with a host of computer environment problems such as a shortage of large-volume and reliable disk storage, shortages of and delays in the delivery of replacement parts, problems with power supplies, and even a shortage of printer paper.

Scientific Networking

For our purposes, the most important development in Soviet networking is Akademset', a nationwide packet-switched Academy research network under development for most of this decade. We shall also discuss network access to databases under the State Automated System of Scientific Technical Information (GASNTI) program, and local area networks (LAN). We will not consider networks for general economic and military applications. In order of apparent importance and extent of use, Soviet networks provide four main services: access to remote computing resources, access to information from remote databases, enhanced scientific communications and enhanced interpersonal communications. The product of these classifications forms the matrix shown in Table 3, where an "x" indicates that a substantial amount of activity is taking place in that area.

Table 3 points out that although there are areas in which the Soviets are active in networking, some areas remain undeveloped. In particular, by Western standards, there is very little activity under interpersonal communications, although several Soviets expect much more in the near future.

In contrast, the United States scientific community enjoys extraordinary access to networking technologies. ARPANET, Bitnet, NSFnet, CSnet, other academic networks, industrial networks, and commercial network vendors together provide tremendous opportunities for interconnectivity. It is safe to say that anyone at a medium or large university will have no problem joining this electronic community. Outside academia, anyone with a personal computer and a modem can join any of a number of commercial network services for a modest fee. The number of publicly accessible on-line databases is approaching 4,000, and NSFnet will give unprecedented access to supercomputers.

The Academy of Sciences has faced difficult obstacles in its project to build a research network to join its institutes. Nevertheless, parts of Akademset' have been operating for at least two years. It is one of the few true wide-area networks to be found in the Soviet Union. The project is run by the Moscow All-Union Scientific Research Institute of Applied Automated Systems (VNIIPAS), and the main development work has been done by the Institute of Electronic Computing Technology (IEVT) in Riga. The major cities–Khabarovsk, Kiev, Leningrad, Moscow, Novosibirsk, Riga, Sverdlovsk, Tashkent, and Vladivostok–are each the center of or participate in regional subnetworks which are then tied together. The Akademset' hosts exchange packets using X.25 protocols at the lower levels. At the higher levels of the Open Systems Interconnection framework–the protocol of the International Standards Organization–to which Akademset' nominally holds,

Table 1. Current Soviet High-Speed Computers

	BESM-6	M-10	El'brus -1,-2	PS-2000	PS-3000	ES-1766	MARS-M	IZOT 1703[a]
Year of introduction[b]	1964	1979	1979 (E-1) ? (E-2)	1983	1984	1984	1986	1987
Country of manufacture	U.S.S.R.	U.S.S.R.	U.S.S.R.	U.S.S.R.	U.S.S.R.	U.S.S.R.	U.S.S.R.	Bulgaria
Number of processors	1	8	1-10	8-64	4	?	4	11
Word length (bits)	50	32	64	24	32	?	48?	32, 38
Main memory (words)	32-128K	1.25M	64-1,024K	32-256K	2M	?	2M	6.5M
Cycle time (nsec)	?	1800	?	320	?	?	?	?
Peak performance (MIPS)	1	5	12 (E-1) 125 (E-2)	200	10-20	100	20 MFLOPS	100-120 MFLOPS

[a] The IZOT 1703 consists of an ES-1037 mainframe with 10 attached ES-2706 array processors. Figures are aggregates across all 11 machines.
[b] These are estimates. The date of first customer delivery is often difficult to determine.

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there are specialized protocols which mainly serve to interface with protocols such as IBM BTAM.

Although Akademset' does qualify as a network, there is not much traffic on it at present, say, as compared with ARPANET. For example, the Moscow to Novosibirsk link is only available for about 9 hours per day and runs at 2400 bits per second (bps), although it could be upgraded to 9600 bps. None of the backbone links runs faster than 9600 bps. There is as yet no dedicated electronic mail service, although files can be sent which contain messages. A multilanguage conferencing and mail system called ADONIS available. Akademset' also provides some access to on-line databases at other sites. It is not having much impact on the scientific community. A general file transfer package will not be completed until March 1989. More important are the regional subnetworks, which do give remote access to large computer centers.

A portion of Akademset', called IASNet, is being created by VNIIPAS to manage access to Eastern Europe and other socialist countries and to Western networks. Theoretically, it will be possible to access foreign databases through Adakemset', although for the time being it is too difficult and expensive to be worthwhile for most researchers.

An alternative West-East link is being provided by the San Francisco-Moscow Teleport, which has established a link with at least eleven organizations in the Soviet Union. Some quantity of satellite equipment and special error-correcting modems have been delivered to the Soviets in order to make high-speed links possible. As of fall 1988, plans to implement a dedicated 750 Kbps T1 circuit were about to be realized. The plan envisioned two data and two voice channels, with provisions for transmitting computer graphics and facsimiles. Ultimately, it will become a for-profit service. Other U.S. and Western organizations are pursuing telecommunications links with the Soviets as well.

Many scientific establishments have built local area networks.

The Soviets have put sizeable resources into bibliographic databases. The State Automated System of Scientific Technical Information (GASNTI) provides access to more than four million document references in databases on various topics. More than 40 sites are being connected directly to the Moscow database host. Throughout the entire system of computerized databases which is being constructed in the Soviet Union, about two million references are being added each year. Other databases with limited online access are being created by the State Committee for Science and Technology, the Institute of Scientific Information on the Social Sciences, and various libraries. There are a fairly large number of information retrieval systems which are functioning in ministries, and some have remote access. In the absence of personal computers, the limited number of modems, and small transmission throughput, remote access to these databases is far less than what is available in the West.

Many Soviet scientific establishments have now built local area networks (LANs) of one sort or another. The principle motivation for these networks has been to run experiments and gain access to bigger machines. It is hard to find any examples of electronic mail use in

Table 2. Overview of Selected Soviet Bloc High-Speed Computers

BESM-6	Developed at the Institute of Precision Mechanics and Computer Technology (ITMVT), this computer brought the Soviets close to world performance and sophistication levels for second generation machines. It incorporates index registers, multiprogramming with memory protection, and associative registers for a limited virtual memory capability. Approximately 200 were produced between 1965 and 1977.
M-10	The M-10 is a synchronous multiprocessor consisting of 8 processors which can be clustered dynamically to processes various data formats, ranging from 16-128 bits. M. A. Kartsev, the chief developer, died in 1983 and little has been heard about this machine since then.
El'brus	Also developed at ITMVT, the El'brus multiprocessors were modelled after the Burroughs B6700/B7700, being a complex of CPUs, I/O processors, data transmission processors, and memory modules. The stack-based architecture supports an Algol 68-like language which is used for job control and for systems and applications programming. A specialized, 125 MFLOPS pipeline processing CPU is under development for inclusion in El'brus-2 configurations. 10-50 El'brus-1s and 3-4 El'brus-2s may be in use. A prototype El'brus-3 is scheduled for completion in 1990.
PS-2000	Developed at the Institute of Control Problems (IPU), Moscow, this single-instruction, multiple-datatream (SIMD) machine consists of up to 64 processing elements (PE) and a control unit. Neighboring PEs are linked by parallel busses. PEs can be clustered by serial channels into groups of 8, 16, or 64 to share local data. The short word-length and difficult programming are the chief limitations. These systems are currently the fastest Soviet systems in series production and are being used in a number of geological applications.
PS-3000	Developed for real-time process control applications, the PS-3000, also developed at IPU, consists of a control processor linked with three computational units. Between two and four such systems can be joined together. The system supports scalar and vector processing, interrupt handling, and provides 256 Mbytes of virtual memory.
ES-1766	This "macro-pipeline" multiprocessor, developed at the Institute of Cybernetics in Kiev, pipeline processes data across processors. Programming is done in MAYaK, a family of languages giving varying degrees of control over how the processors execute algorithms.
MARS-M	The "Modular, Asynchronous, Expandable System" (MARS) consists of four pipeline processors which incorporate parallelism from the process to the instruction level. Asynchronously communicating modules organized in a hierarchy provide this parallelism while limiting the complexity of control. Currently, hardware component and software prototypes have been developed.
IZOT 1703	Developed as a joint effort between Bulgarian firms and the Soviet Institute of Space Research (IKI), Moscow, the IZOT 1703 consists of an ES-1037 general-purpose mainframe attatched to up to 10 ES-2706 array processors each capable of 12 MFLOPS. The array processors are architecturally similar to those developed by Floating Point Systems, Inc., Beaverton, Ore. The Bulgarians have reportedly produced over 30 of these systems.

these LANs. The machines in use are most often mini- and microcomputers which use the PDP-11 instruction set, and in some instances DECNET protocols have been used. Some institutes have created their own protocols, while others settle for hierarchical arrangements which should not really be considered LANs. Transmission speeds are not particularly fast, partially because of the unavailability of specialized hardware chips for collision detection and protocol implementation. Despite these drawbacks, the LANs have probably had the biggest impact of the three application areas–wide area networks, databases, and LANs–considered here, because they have provided interactive computing access for a fairly large number of researchers.

Structural Problems

The Soviet general purpose telephone system is fragmented and shot through with old electromechanical technology. Only by 1990 is it expected that 85% of the country's 3,600 regional centers will have direct dial for domestic long distance. Despite large increases in investment in the telephone system in the 1986-1990 plan period, series production of the necessary equipment has been problematical, especially in the absence of sufficient test equipment. Although fiber optics lines are being installed and all-digital trunk lines are appearing between cities, intracity connections still present problems for networking. Maintaining connec-

tions above 300-1200 bps without special error-correcting modems is difficult. Any form of remote acess from home is therefore tedious, if not impractical. Organizations that might want to use the general purpose telephone system for digital networks would have a hard time doing so.

Three other options for building networks are available, but each has its own drawbacks. The PD-200 network, which has some automatic error-recovery capabilities, was only designed to function at 200 bps and probably provides no more than 1200 bps now. The switched telegraph network is no faster than 200 bps. Leased lines, therefore, are about the only viable option for serious networking. It can take a long time, however, to obtain them, and their cost is high. Satellite use for telecommunications has been minimal in the past, although it is increasing.

Soviet networking applications also suffer from a shortage of hardware. Few Soviet researchers have their own personal computers and modems, especially at home or in quantities sufficiently large to equip the private offices of scientific workers. However, personal computers at, say the IBM PC/XT level, are starting to appear in Soviet institutes, and we can expect to see them become more widely available for this community within the next few years. At present, access to networks at the institutes usually requires going to a terminal room.

Many Soviet mainframes also have drawbacks for networking applications. The ES IBM-like mainframes run pre-Systems Network Architecture (SNA)–the IBM protocol–or early SNA-like software packages, have relatively small amounts of disk space available, break down often, and are slow. Almost all Soviet "networks" are primarily hierarchical in nature and are better described as time-sharing hosts connected to remote job entry stations.

Another reason that networking is just getting off the ground in the Soviet Union is the lack of demand for it. Soviet researchers have traditionally been quite isolated. It is not uncommon for a scientist to work in the same institute all of his life. Joint projects between institutes are relatively uncommon. Local maintenance of computers has resulted in incompatible systems software, which has reduced incentives for sharing and joint access to remote computers. The industrial institutes, where a large proportion of the development work takes place, are additionally isolated by ministerial barriers. Academics in the Academy or universities are often not well-positioned to influence organizations such as the Ministry of Communications, which provides communications lines.

Few researchers have their own personal computers and modems.

The absence of a strong demand of enterprises to be connected to their ministries and to other enterprises has drastically reduced the commercial demand for networks in comparison with demand in the U.S. The computing infrastructure consequently has provided little specialized hardware which might be adopted by the scientific community. For example, the ES 837x front-end processor, which emulates the IBM 370x machines and is important for SNA-type applications, was first shown around 1979, but in the last ten years, has hardly been in evidence in networking applications. In the U.S., it is quite easy to buy specialized boards to put any personal computer onto a LAN, but such boards are difficult if not impossible to find in the Soviet Union.

Despite recent advances in high-speed computing and network development, the Soviet scientific community remains hindered by a host of technological deficiencies and systemic obstacles.

Soviet activity in the development of supercomputers, minisupers, and machines with parallel/concurrent architectures has increased significantly in the last decade. Nevertheless, not counting modest IBM-like ES configurations, probably fewer than 75 high-speed systems of any kind produced after 1977 are currently in use. In contrast, Cray Research Inc., Minneapolis, Minn., alone has installed more than 200 machines in the same time period, with even the oldest significantly more powerful than all but a handful of the Soviet systems. In addition to insufficient computing power, Soviet scientists must also contend with a host of support problems.

Support Increases

Recent political and organizational changes will help accelerate the development of systems more suitable for large scale scientific computing. Increased levels of political support will channel more resources to systems researchers and producers and should result in improved integration between them.

Yet these changes by themselves are not likely to greatly improve the state of scientific computing in the near future. Production rates for existing high-speed systems may not increase dramatically, and systems currently in prototype or near-prototype stages will not be available in significant quantities for several more years. Qualitative and quantitative deficiencies in peripheral devices will remain. In the short term, existing BESM-6s and modest ES mainframes, with or without array processors, will support the bulk of large scale scientific computing.

Table 3. Some Areas of Networking Activity in the Soviet Union

Purpose of Use	Akademset'	GASNTI	LAN
Access to Computing Resources	x		x
Access to Scientific Information	x	x	
Enhanced Scientific Communication	x		x
Enhanced Interpersonal Communication			

Consisting of a control processor linked with three computational units, the PS-3000 multiprocessor system supports scalar and vector processing as well as interrupt handling.

Most Soviet researchers have not yet begun to take advantage of what is technically possible with professional-level personal computing, let alone networking. It is within Soviet capability to build reasonably modern packet-switched networks, although the absence of economies of scale make it expensive. The telecommunications infrastructure and the installed hardware base is such that it will take major investment and considerable time before widespread access to networking technologies, especially from home computers, becomes a reality. Akademset' will be expanded and elite groups of scientists will be able to use it to carry out important work, but the kind of total interconnectivity which is now enjoyed by U.S. scientists is still well in the future for the Soviet Union. Electronic mail communication will grow much more slowly than it has in the U.S. because of the slower rate of introduction of personal computers, the lower throughput of communications channels, and the traditional isolation of Soviet scientific institutions. Access to remote computing resources will depend at least as much on the establishment of the resources as on networking technologies. Database access will continue to grow and may prove to be one of the most important networking applications in the near term.

The prospects for networking, to a greater extent than for high-speed scientific computers, depend partially on the success of the *perestroika* reforms. Greater openness and expanded international exposure for the Soviet scientific community, and new organizational arrangements may increase the need and desire for networking. In particular, the new Interbranch Scientific Technological Complexes cross many organizational boundaries. The atmosphere of openness will certainly contribute to a willingness to allow the free communications afforded by electronic mail. Access to databases which outline foreign achievements is becoming more important as the state stresses the need to be current. Increased investment in computing and telecommunications industries may help speed the supply of better quality networking possibilities.

Soviet researchers are still far away from total interconnectivity.

There are more general differences between contemporary Soviet and American scientific computing. During the 1980s, scientific computing in the U.S., and in the "West" more globally (now including significant Far Eastern representation), has been dramatically changed by the extensive and intensive mixing and interconnecting of large numbers of increasingly powerful workstations with increasingly sophisticated graphics, high-end high-speed machines, direct instrument connections, and telecommunications. Access to such facilities has become extraordinarily distributed in a short period of time. In spite of some embryonic developments, for the most part the Soviet scientific community has had to endure the frustration of nonparticipation.

FOR FURTHER READING

The following articles provide further information:

William K. McHenry, "Computer Networks in the Soviet Scientific Community," in *The Status of Soviet Civil Science*, Craig Sinclair, ed., *Proceedings of the Symposium on Soviet Scientific Research*, NATO, Brussels, Belgium, Sept. 24-26, 1986, Martinus Nijhoff, Dordrecht, 1987, p. 151-176.

Roald Z. Sagdeev, "Science and Perestroika: A Long Way to Go," *Issues in Science and Technology*, v. IV, 4 (Summer 1988), p. 48-52.

Peter Wolcott and Seymour E. Goodman, "High-Speed Computers of the Soviet Union," *IEEE Computer*, (Sept., 1988), p.32-41. ■